

On the ridge-like structures in the nuclear and hadronic reactions

S.M. Troshin, N.E. Tyurin

*Institute for High Energy Physics,
Protvino, Moscow Region, 142281, Russia*

Abstract

We briefly comment on the ridge-like structure origin in the nuclear and hadronic reactions emphasizing that this structure in the two-particle correlation function can result from the rotation of the transient state of matter.

It is well known that the studies of multiparticle production in hadron and nucleus processes provide a clue to the mechanisms of deconfinement and hadronization. The deconfined state found at RHIC reveals the properties of the perfect liquid, being strongly interacting collective state [1].

Nowadays, when experimental program of the LHC has started, it is important to analyze newly obtained experimental data and try to make first conclusions on the nature of a matter produced in pp collisions, i.e. is it weakly interacting or it remains to be a strongly interacting one as it was observed at RHIC in AA collisions? In the latter case one can expect that proposed in [2] mechanism related to the rotation of transient matter should be working at the LHC energies and therefore the observed at RHIC phenomena should be observed in pp -collisions also.

The ridge structure was observed first at RHIC in peripheral collisions of nuclei in the two-particle correlation function in the near-side jet production (cf. recent paper [4] and references therein). It was demonstrated that the ridge particles have a narrow $\Delta\phi$ correlation distribution (where ϕ is an azimuthal angle) and wide $\Delta\eta$ correlations (η is a pseudorapidity). The ridge phenomenon was associated with the collective effects of a medium.

The similar structure in the two-particle correlation function was observed by the CMS Collaboration [5]. This is rather surprising result because the ridge structure was observed for the first time in pp -collisions. Those collisions are commonly treated as the kind of “elementary” ones under the heavy-ion studies and therefore often used as the reference process for detecting deconfined phase formation on the base of difference between pp - and AA -collisions. It is evident now that such approach should be revised in view of this new and unexpected experimental result.

The particle production mechanism proposed in the model [2] takes into account the geometry of the overlap region and dynamical properties of the transient state in hadron interaction. This picture assumes deconfinement at the initial stage of interaction. The transient state appears as a rotating medium of massive quarks and pions which hadronize and form multiparticle final state. Essential point for this rotation is the non-zero impact parameter in the collision.

Indeed, the inelastic overlap function $h_{inel}(s, b)$,

$$h_{inel}(s, b) \equiv \frac{1}{4\pi} \frac{d\sigma_{inel}}{db^2},$$

has a peripheral impact parameter dependence at the energy $\sqrt{s} = 7$ TeV due to the reflective scattering [3]. Note, that unitarity equation rewritten at high energies for the elastic amplitude $f(s, b)$ has the form

$$\text{Im}f(s, b) = h_{el}(s, b) + h_{inel}(s, b)$$

and $h_{inel}(s, b)$ is the sum of all inelastic channel contributions. Due to this peripherality, the mean multiplicity

$$\langle n \rangle(s) = \frac{\int_0^\infty b db \langle n \rangle(s, b) h_{inel}(s, b)}{\int_0^\infty b db h_{inel}(s, b)}$$

gets the main contribution from the collisions with non-zero impact parameters. Thus, one can assume that the events with high multiplicity at the LHC energy $\sqrt{s} = 7$ TeV correspond to the peripheral hadron collisions [3]. Thus, at the LHC energy $\sqrt{s} = 7$ TeV there is a dynamical selection of peripheral region in impact parameter space responsible for the inelastic processes. In the nuclear reactions such selection is provided by the relevant experimental adjustments. Note, that the ridge-like structure in the nuclear reactions has also been observed in peripheral collisions only [4].

The geometrical picture of hadron collision at non-zero impact parameters implies that the generated massive virtual quarks in overlap region could obtain very large initial orbital angular momentum at high energies. Due to strong interaction between quarks this orbital angular momentum leads to the coherent rotation of the quark system located in the overlap region as a whole in the xz -plane (Fig. 1). This rotation is similar to the liquid rotation where strong correlations between particles momenta exist. Thus, the orbital angular momentum should be realized as a coherent rotation of the quark-pion liquid as a whole. The assumed particle production mechanism at moderate transverse momenta is an excitation of a part of the rotating transient state of massive constituent quarks (interacting by pion exchanges). Due to the fact that the transient matter is strongly interacting, the

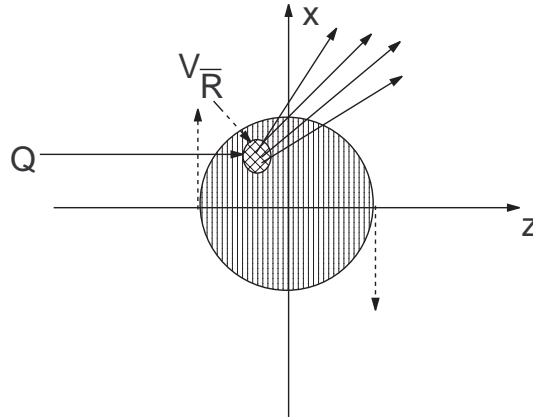


Figure 1: *Interaction of the constituent quark with rotating quark-pion liquid.*

excited parts should be located closely to the periphery of the rotating transient

state otherwise absorption would not allow to quarks and pions leave the interaction region (quenching).

The mechanism is sensitive to the particular direction of rotation and to the rotation plane orientatation. This will lead to the narrow distribution of the two-particle correlations in $\Delta\phi$. However, two-particle correlation could have broad distribution in polar angle ($\Delta\eta$) in the above mechanism (Fig. 1). Quarks in the exited part of the cloud could have different values of the two components of the momentum (with its third component lying in the rotation xz -plane) since the exited region $V_{\bar{R}}$ has significant extension.

Thus, the ridge-like structure observed in the high multiplicity events by the CMS Collaboration can be an experimental manifestation of the coherent rotation of the transient matter in hadron collisions. The narrowness of the two-particle correlation distribution in the asimuthal angle is the distinctive feature of this mechanism.

There should be other experimentally observed effects of this collective effect, one of them is the directed flow v_1 in hadron reactions, with fixed impact parameter discussed in [2]. Rotation of transient matter will affect also elliptic flow v_2 and average transverse momentum of secondary particles produced in proton-proton collisions [6]. Due to rotation the density of massive quarks will be different in the different parts of the rotating cloud, it will be smaller in the central part and bigger at the peripheral part of cloud due to the centrifugal effect. At the same time the quarks in the peripheral part have a maximal transverse momenta and therefore we should observe correlation of the multiplicity and transverse momentum. It would lead, in particular, to the following relation of the average transverse momentum with the mean multiplicity of secondaries

$$\langle p_T \rangle(s) = a + b \langle n \rangle(s).$$

This relation is in a good agreement with experimental data [6].

The above discussion shows that the nature of the state of matter revealed at the LHC in proton collisions is the same as the nature of the state revealed at RHIC in nuclei collisions.

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